(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 June 2006 (29.06.2006)

PCT

(10) International Publication Number
WO 2006/067116 A1

(51) International Patent Classification:
C12N 9/64 (2006.01)   *C07K 14/745* (2006.01)
C12N 9/04 (2006.01)

(21) International Application Number:
PCT/EP2005/056916

(22) International Filing Date:
19 December 2005 (19.12.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
PA 2004 01966   21 December 2004 (21.12.2004)   DK

(71) Applicant *(for all designated States except US)*: NOVO NORDISK HEALTH CARE AG [CH/CH]; Andreasstrasse 15, CH-8050 Zurich (CH).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)*: STEENSTRUP, Thomas, Dock [DK/DK]; Grænsevej 14, DK-2820 Gentofte (DK).

(74) Agent: NOVO NORDISK A/S; Corporate Patents, Novo Allé, DK-2880 Bagsværd (DK).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
— with sequence listing part of description published separately in electronic form and available upon request from the International Bureau

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: EXPRESSION OF GAMMA-CARBOXYLATED POLYPEPTIDES IN GAMMA-CARBOXYLATION DEFICIENT HOST SYSTEMS

(57) Abstract: The present invention relates to a novel method for preparing gamma-carboxylated poly-peptides, including coagulation Factors VII, IX, X and Protein C. The present invention also relates to novel host cells and recombinant vectors to be used in this improved method for preparing gamma-carboxylated polypeptides.

TITLE

Expression of Gamma-Carboxylated Polypeptides in Gamma-Carboxylation Deficient Host Systems

5   **FIELD OF THE INVENTION**

The present invention relates to a novel method for preparing gamma-carboxylated poly-peptides, including coagulation Factors VII, IX, X and Protein C. The present invention also relates to novel host cells and recombinant vectors to be used in this improved method for preparing gamma-carboxylated polypeptides.

10

BACKGROUND OF THE INVENTION

Vitamin-K dependent coagulation factors require gamma-carboxylation of the Gla-domain for activity. Gamma-carboxylic acid, abbreviated Gla, is an amino acid found in certain calcium-binding proteins. These proteins include factor VII, factor IX, factor X,

15   prothrombin, Protein C and Protein S, plasma proteins that are components of the coagu-lation system; Protein Z, also found in plasma, pulmonary surfactant-associated proteins (Rannels et al. Proc. Natl. Acad. Sci. USA 84: 5952-56, 1987), and the bone proteins os-teocalcin (also known as bone gla-protein) and matrix gla-protein. Proteins containing this amino acid are variously referred to as "Vitamin K-dependent proteins", "gla-

20   proteins", or "gamma-carboxylated proteins." The plasma vitamin K-dependent proteins are dependent on gla-mediated binding to calcium and membrane phospholipids for their biological activity.

The gene for the gamma-carboxylase has been known for many years. However, the

25   gamma-carboxylase is not sufficient for gamma-carboxylation, and transfection and ex-pression of the gamma-carboxylase neither enables gamma-carboxylation in a gamma-carboxylation-deficient host cell, nor enhances the gamma-carboxylation in a gamma-carboxylation-efficient host cell.

30   Gamma-glutamyl carboxylase is an integral membrane microsomal enzyme located in the rough endoplasmic reticulum. It carboxylates glutamate residues located in the Gla domain of the vitamin K-dependent proteins. Human gamma-glutamyl carboxylase cDNA has re-cently been isolated and sequenced (Wu SM et al. Science 254:1634, 1991). Studies of the biosynthesis of vitamin K-dependent proteins in BHK and CHO cells show that the carboxy-

35   lase is present in both the endoplasmatic reticulum (ER) and the Golgi complex, and that the pro-peptide, containing the carboxylase recognition site, is cleaved after completion of the gamma-carboxylation. Speculation surrounds whether the pro-peptide stimulates the

2

carboxylase activity (Sigiura, I. et al. (1997) Proc.Natl.Acad.Sci., 9, 9069-9074, Knobloch and Suttie (1987) J.Biol.Chem. 262, 15334-15337, Furie et al (1999) Blood, 93, 1798-1808).

5   The biosynthesis of vitamin K-dependent proteins includes several post-translational proc-
       essing steps before a mature functional protein is obtained. Vitamin K is a necessary cofac-
       tor for the gamma-carboxylation of glutamic acid residues in these vitamin K-dependent
       proteins, including the procoagulant factors thrombin, factors VII, IX, and X; the anticoagu-
       lants Protein C and Protein S; and other proteins such as osteocalcin (bone Gla protein),
10   matrix Gla protein, and proline-rich Gla protein 1. Gamma-carboxylation permits the co-
       agulation proteins to undergo a conformational change necessary both for calcium-
       dependent complexing of vitamin K-dependent proteins to their cofactors on phospholipid
       surfaces and for their biologic activity. Gamma-carboxylation of vitamin K-dependent
       coagulation factors is catalyzed by a carboxylase that requires the reduced form of vita-
15   min K (vitamin KH_2), molecular oxygen, and carbon dioxide. During this reaction, vita-
       min KH_2 is oxidized to vitamin K epoxide, which is recycled by vitamin K epoxide reduc-
       tase to vitamin K. Cloning and expression of the vitamin K 2,3-epoxide reductase
       (VKOR), Li et al., Nature 427:541-544, 2004, was recently published.

20   Blood coagulation is a process consisting of a complex interaction of various blood compo-
       nents, or factors, which eventually gives rise to a fibrin clot. Generally, the blood compo-
       nents which participate in what has been referred to as the coagulation "cascade" are pro-
       enzymes or zymogens, enzymatically inactive proteins which are converted to proteolytic
       enzymes by the action of an activator, itself an activated clotting factor. Coagulation factors
25   that have undergone such a conversion and generally referred to as "active factors," and
       are designated by the addition of a lower case "a" suffix (e.g., activated factor VII (FVIIa)).

       Activated factor X (FXa) is required to convert prothrombin to thrombin, which then con-
       verts fibrinogen to fibrin as a final stage in forming a fibrin clot. There are two systems, or
30   pathways, that promote the activation of FX. The "intrinsic pathway" refers to those reac-
       tions that lead to thrombin formation through utilization of factors present only in plasma.
       A series of protease-mediated activations ultimately generates factor IXa which, in conjunc-
       tion with factor VIIIa, cleaves FX into FXa. A similar proteolysis is effected by FVIIa and its
       co-factor, tissue factor, in the "extrinsic pathway" of blood coagulation. Tissue factor is a
35   membrane bound protein and does not normally circulate in plasma. Upon vessel disrup-
       tion, however, it can complex with FVIIa to catalyze FX activation or factor IX activation in
       the presence of Ca++ and phospholipid.   While the relative importance of the two coagu-

lation pathways in haemostasis is unclear, in recent years FVII and tissue factor have been found to play a pivotal role in the regulation of blood coagulation.

FVII is a trace plasma glycoprotein that circulates in blood as a single-chain zymogen. The zymogen is clot inactive. Single-chain FVII may be converted to two-chain FVIIa by FXa, factor XIIa, factor IXa or thrombin *in vitro*. FXa is believed to be the major physiological activator of FVII. Like several other plasma proteins involved in haemostasis, FVII is dependent on vitamin K for its biosynthesis, which is required for the gamma-carboxylation of 10 glutamic acid residues in the amino terminus of the protein. The intracellular post-translational processing of FVII takes place in the endoplasmatic reticulum (ER) and the Golgi complex. Besides the vitamin K-dependent gamma-carboxylation, FVII is subjected to limited proteolysis to remove the N-terminal propeptide, and glycosylation of asparagine-145 and -322, and serine-52 and -60.

The gamma-carboxylated glutamic acid (Gla) residues are required for the metal-associated interaction of FVII with phospholipids. In the presence of tissue factor, phospholipids and calcium ions, the two-chain FVIIa rapidly activates FX or factor IX by limited proteolysis.

Protein C is a naturally occurring serine protease anticoagulant that plays a role in the regulation of homeostasis by inactivating factors Va and VIIIa in the coagulation cascade. Human protein C is made *in vivo* primarily in the liver as a single polypeptide of 461 amino acids. This single chain precursor molecule undergoes multiple post-translational modifications including carboxylation of nine glutamic acid residues, resulting in nine Gla residues.

Protein S also exhibits anticoagulant activity in *in vitro* clotting assays. Protein S demonstrates anticoagulant cofactor activity for activated protein C. Protein S has also been shown to be an anticoagulant factor in the absence of activated protein C as it can inhibit prothrombinase activity in assays free of activated protein C, and binds to Factor Va or Factor Xa and functions as an anticoagulant without activated protein C. Protein S is physiologically a very important antithrombotic factor since hereditary or acquired deficiencies of protein S are associated with venous and arterial thrombotic disease. A deficiency of free protein S with a normal level of total protein S has been described in some patients with thrombotic disease. It is often necessary to selectively block the coagulation cascade in a patient. Anticoagulants such as protein C or protein S may be used, for example, during kidney dialysis, or to treat deep vein thrombosis, disseminated intravascular coagulation (DIC), a patient at risk for acute thrombosis, protein S deficiency, sepsis, inflammation, cancer, patients undergoing surgery, and a host of other medical disorders.

Osteocalcin is composed of 49 amino acid residues which include three Gla residues. The function of this protein is thought to be to suppress excessive mineralization. Osteocalcin is a bone-specific protein that is secreted by osteoblasts. A fraction of newly synthesized os-

5   teocalcin is released into the bloodstream, where its concentration correlates with the indices of osteoblastic activity and bone formation rate. In humans, changes in circulating osteocalcin levels have been associated with metabolic bone diseases such as osteoporosis and hyperparathyroidism.

10   Matrix Gla Protein (MGP) is composed of 79 amino acids including 5 Gla residues. This protein is usually found in demineralized matrix and believed to have a certain function in the initiation of bone formation.

Gamma-carboxylation has only been demonstrated in selected host systems such as

15   mammalian cells and a snail species, *Conus textile*. More efficient protein production host systems, such as yeast and insect cells, do not possess gamma-carboxylation capabilities and thus, cannot be used for the production of vitamin-K dependent coagulation factors. Therefore, a need in the art for improved systems for the production of recombinant vitamin K-dependent proteins and particular recombinant coagulation factors still ex-

20   ists. The present invention fulfils this need by providing a method that gives a more efficient, faster production and/or higher yield of recombinant vitamin K-dependent proteins, in particular FVII.

This invention demonstrates that expression of the gamma-carboxylase together with

25   VKOR can enable a carboxylation-deficient host cell to gamma-carboxylate vitamin-K dependent coagulation factors. Additionally, over-expression of the two enzymes enhances already present gamma-carboxylation in, for example, CHO cells or transgenic animals.

SUMMARY OF INVENTION

30   The present invention relates to a novel method for preparing vitamin K-dependent proteins and in particular coagulation factor VII (FVII).

The invention also relates to a method of activating a gene encoding a vitamin K-dependent protein present in primary, secondary, or immortalized cells of vertebrate ori-

35   gin, which is normally not expressed in the cells, or is not expressed at physiologically significant levels in the cells as obtained.

The present invention also relates to host cells containning vectors capable of producing vitamin K-dependent polypeptides.

The present invention also relates to vectors containing nucleic acid molecules encoding for vitamin K-dependent polypeptides.

BRIEF DESCRIPTION OF THE DRAWINGS
FIG. 1: Shows details of the pTS86-Hyg plasmid.
FIG. 2: Shows details of the pTS75 plasmid.
FIG. 3: Shows details of the FVII HSA/MF(alpha)1 signal p425 plasmid.
FIG. 4: Shows details of the VKOR pRS316-MF(alpha)1 promoter plasmid.
FIG. 5: Shows details of the VKOR pRS426-MF(alpha)1 promoter plasmid.
FIG. 6: Shows details of the VKOR C-HA-tag pRS316-MF(alpha)1 promoter plasmid.
FIG. 7: Shows details of the VKOR C-HA-tag pRS426-MF(alpha)1 promoter plasmid.
FIG. 8: Shows details of the gamma-carboxylase pRS313 MF(alpha)1 promoter plasmid.
FIG. 9: Shows details of the gamma-carboxylase pRS423 MF(alpha)1 promoter plasmid.
FIG. 10: Shows details of the gamma-carboxylase C-term myc-tag pRS313 MF(alpha)1 promoter plasmid.
FIG. 11 Shows details of the gamma-carboxylase C-term myc-tag pRS423 MF(alpha)1 promoter plasmid.

DETAILED DESCRIPTION OF THE INVENTION
Expression of a polynucleotide encoding the vitamin K-dependent protein can be obtained either by transfecting the gene of interest into a cell, or by activating (i.e., turning on) an endogenous gene encoding the vitamin K-dependent protein already present in primary, secondary, or immortalized cells of vertebrate origin, which is normally not expressed in the cells or is not expressed at physiologically significant levels in the cells as obtained. For activating genes of interest, homologous recombination can be used to replace or disable the regulatory region normally associated with the gene in cells as obtained with a regulatory sequence which causes the gene to be expressed at levels higher than evident in the corresponding non-transfected cell, or to display a pattern of regulation or induction that is different than evident in the corresponding non-transfected cell.

The term "eucaryotic host cell", as used herein, represenst any cell, including hybrid cells, in which heterologous DNA can be expressed. Typical host cells includes, but are not limited to insect cells, yeast cells, mammalian cells, including human cells, such as

6

BHK, CHO, HEK, and COS cells. Examples of mammalian cells, yeast cells, other fungal cells, and insect cells suitable in practising the present invention are provided below.

The term "polynucleotide" denotes a single- or double-stranded polymer of deoxyribonu-
5   cleotide or ribonucleotide bases read from the 5' to the 3' end. Polynucleotides include RNA and DNA, and may be isolated from natural sources, synthesized in vitro, or pre-pared from a combination of natural and synthetic molecules. The length of a polynu-cleotide molecule is given herein in terms of nucleotides (abbreviated "nt") or base pairs (abbreviated "bp"). The term "nucleotides" is used for both single- and double-stranded
10   molecules where the context permits. When the term is applied to double-stranded molecules it is used to denote overall length and will be understood to be equivalent to the term "base pairs". It will be recognized by those skilled in the art that the two strands of a double-stranded polynucleotide may differ slightly in length and that the ends thereof may be staggered as a result of enzymatic cleavage; thus all nucleotides
15   within a double-stranded polynucleotide molecule may not be paired. Such unpaired ends will in general not exceed 20 nt in length.

The term "pro-peptide", as used herein, represent any amino acid sequence, which can bind a gamma-glutamyl carboxylase. Typical pro-peptides that direct a gamma-
20   carboxylation of vitamin K-dependent proteins are found at the N-terminal of a vitamin K-dependent protein and serves as a docking site or recognition sequence for interaction with gamma-glutamyl carboxylase, which carboxylates glutamate residues usually located in the Gla domain of vitamin K-dependent proteins. There may be more than one binding site for the gamma-glutamyl carboxylase, e.i., gamma-glutamyl carboxylase
25   recognition sequence, in one pro-peptide. One example of a pro-peptide within this definition is thus the natural pro-peptide sequence of FVII. Another example within this definition is the natural pro-peptide sequence of FVII connected to the natural pro-peptide sequence of factor IX within the same amino acid sequence.

30   The term "expression unit", as used herein, means a polynucleotide comprising the following operably linked elements: (a) a transcription promoter; (b) a polynucleotide sequence encoding an amino acid sequence; and (c) a transcription terminator. An example of an expression unit is thus a DNA vector comprising the following linked elements: (a) a transcription promoter, (b) a cDNA sequence encoding a coagulation
35   protein; and (c) a transcription terminator.

The term "vector", as used herein, means any nucleic acid entity capable of the amplification in a host cell. Thus, the vector may be an autonomously replicating vector, i.e. a vector, which exists as an extra-chromosomal entity, the replication of which is independent of chromosomal replication, e.g. a plasmid. Alternatively, the vector may be

5   one which, when introduced into a host cell, is integrated into the host cell genome and replicated together with the chromosome(s) into which it has been integrated. The choice of vector will often depend on the host cell into which it is to be introduced. Vectors include, but are not limited to plasmid vectors, phage vectors, viruses or cosmid vectors. Vectors usually contain a replication origin and at least one selectable gene, i.e., a gene

10   which encodes a product which is readily detectable or the presence of which is essential for cell growth.

The term "promoter" denotes a portion of a gene containing DNA sequences that provide for the binding of RNA polymerase and initiation of transcription. Promoter sequences

15   are commonly, but not always, found in the 5' non-coding regions of genes.

The term "binding sequence for a gamma-glutamyl carboxylase" as used herein means the necessary amino acid residues within a sequence (i.e. recognition sequence) for binding or docking or interaction with a gamma-glutamyl carboxylase.

20

Polypeptides
The term "vitamin K-dependent protein", as used herein, means any protein that is gamma-carboxylated on glutamic acid residues. Typical vitamin K-dependent proteins includes but are not limited to the procoagulant factors thrombin, factor VII, IX, and X;

25   the anticoagulants protein C and protein S; and other proteins such as osteocalcin (bone Gla protein), matrix Gla protein, and proline-rich Gla protein 1.

The terms "factor VII", or "FVII" as used herein means a product consisting of the unactivated form (factor VII). The term "factor VIIa", or "FVIIa" as used herein means a

30   product consisting of the activated form (factor VIIa). This includes proteins that have the amino acid sequence 1-406 of native human factor FVII or FVIIa. It also includes proteins with a slightly modified amino acid sequence, for instance, FVII variants and proteins having a modified N-terminal end including N-terminal amino acid deletions or additions so long as those proteins substantially retain the activity of FVIIa. "FVII" or "FVIIa"

35   within the above definition also includes natural allelic variations that may exist and occur from one individual to another. Also, degree and location of glycosylation or other

8

post-translation modifications may vary depending on the chosen host cells and the nature of the host cellular environment.

The term "variants", as used herein, is intended to designate a vitamin K-dependent pro-
5   tein, e.g. FVII, wherein one or more amino acid residues of the parent protein have been
substituted by another amino acid residue and/or wherein one or more amino acid residues
of the parent protein have been deleted and/or wherein one or more amino acid residues
have been added to the parent protein. Such addition can take place either at the N-
terminal end or at the C-terminal end of the parent protein or both.
10

In the present specification, amino acid residues are represented using abbreviations ap-
proved by IUPAC-IUB Commission on Biochemical Nomenclature (CBN). With respect to
amino acids and the like having isomers, those which are represented by the following
abbreviations are in natural L-form. Further, the left and right ends of an amino acid se-
15   quence of a peptide are, respectively, the N- and C-termini unless otherwise specified.

Non-limiting examples of Factor VII variants having substantially the same or increased
proteolytic activity compared to recombinant wild type human Factor VIIa include S52A-
FVIIa, S60A-FVIIa (Lino et al., Arch. Biochem. Biophys. 352: 182-192, 1998); FVIIa
20   variants exhibiting increased proteolytic stability as disclosed in U.S. Patent No.
5,580,560; FVII variants as disclosed in PCT/DK02/00189 (corresponding to WO
02/077218); FVII variants exhibiting increased proteolytic stability as disclosed in WO
02/38162 (Scripps Research Institute); FVII variants having a modified Gla-domain and
exhibiting an enhanced membrane binding as disclosed in WO 99/20767, US patents US
25   6017882 and US 6747003, US patent application 20030100506 (University of Minne-
sota) and WO 00/66753, US patent applications US 20010018414, US 2004220106, and
US 200131005, US patents US 6762286 and US 6693075 (University of Minnesota); and
FVII variants as disclosed in WO 01/58935, US patent US 6806063, US patent application
20030096338 (Maxygen ApS), WO 03/93465 (Maxygen ApS), WO 04/029091 (Maxygen
30   ApS), WO 04/083361 (Maxygen ApS), and WO 04/111242 (Maxygen ApS), as well as in
WO 04/108763 (Canadian Blood Services).

Non-limiting examples of FVII variants having increased biological activity compared to
wild-type FVIIa include FVII variants as disclosed in WO 01/83725, WO 02/22776, WO
35   02/077218, PCT/DK02/00635 (corresponding to WO 03/027147), Danish patent applica-
tion PA 2002 01423 (corresponding to WO 04/029090), Danish patent application PA
2001 01627 (corresponding to WO 03/027147); WO 02/38162 (Scripps Research Insti-

9

tute); and FVIIa variants with enhanced activity as disclosed in JP 2001061479 (Chemo-
Sero-Therapeutic Res Inst.).

Examples of variants of factor VII include, without limitation, L305V-FVII,
5   L305V/M306D/D309S-FVII, L305I-FVII, L305T-FVII, F374P-FVII, V158T/M298Q-FVII,
V158D/E296V/M298Q-FVII, K337A-FVII, M298Q-FVII, V158D/M298Q-FVII,
L305V/K337A-FVII, V158D/E296V/M298Q/L305V-FVII, V158D/E296V/M298Q/K337A-
FVII, V158D/E296V/M298Q/L305V/K337A-FVII, K157A-FVII, E296V-FVII, E296V/M298Q-
FVII, V158D/E296V-FVII, V158D/M298K-FVII, and S336G-FVII, L305V/K337A-FVII,
10 L305V/V158D-FVII, L305V/E296V-FVII, L305V/M298Q-FVII, L305V/V158T-FVII,
L305V/K337A/V158T-FVII, L305V/K337A/M298Q-FVII, L305V/K337A/E296V-FVII,
L305V/K337A/V158D-FVII, L305V/V158D/M298Q-FVII, L305V/V158D/E296V-FVII,
L305V/V158T/M298Q-FVII, L305V/V158T/E296V-FVII, L305V/E296V/M298Q-FVII,
L305V/V158D/E296V/M298Q-FVII, L305V/V158T/E296V/M298Q-FVII,
15 L305V/V158T/K337A/M298Q-FVII, L305V/V158T/E296V/K337A-FVII,
L305V/V158D/K337A/M298Q-FVII, L305V/V158D/E296V/K337A–FVII,
L305V/V158D/E296V/M298Q/K337A-FVII, L305V/V158T/E296V/M298Q/K337A-FVII,
S314E/K316H-FVII, S314E/K316Q-FVII, S314E/L305V-FVII, S314E/K337A-FVII,
S314E/V158D-FVII, S314E/E296V-FVII, S314E/M298Q-FVII, S314E/V158T-FVII,
20 K316H/L305V-FVII, K316H/K337A-FVII, K316H/V158D-FVII, K316H/E296V-FVII,
K316H/M298Q-FVII, K316H/V158T-FVII, K316Q/L305V-FVII, K316Q/K337A-FVII,
K316Q/V158D-FVII, K316Q/E296V-FVII, K316Q/M298Q-FVII, K316Q/V158T-FVII,
S314E/L305V/K337A-FVII, S314E/L305V/V158D-FVII, S314E/L305V/E296V-FVII,
S314E/L305V/M298Q-FVII, S314E/L305V/V158T-FVII, S314E/L305V/K337A/V158T-FVII,
25 S314E/L305V/K337A/M298Q-FVII, S314E/L305V/K337A/E296V-FVII,
S314E/L305V/K337A/V158D-FVII, S314E/L305V/V158D/M298Q-FVII,
S314E/L305V/V158D/E296V-FVII, S314E/L305V/V158T/M298Q-FVII,
S314E/L305V/V158T/E296V-FVII, S314E/L305V/E296V/M298Q-FVII,
S314E/L305V/V158D/E296V/M298Q-FVII, S314E/L305V/V158T/E296V/M298Q-FVII,
30 S314E/L305V/V158T/K337A/M298Q-FVII, S314E/L305V/V158T/E296V/K337A-FVII,
S314E/L305V/V158D/K337A/M298Q-FVII, S314E/L305V/V158D/E296V/K337A-FVII,
S314E/L305V/V158D/E296V/M298Q/K337A-FVII,
S314E/L305V/V158T/E296V/M298Q/K337A-FVII, K316H/L305V/K337A-FVII,
K316H/L305V/V158D-FVII, K316H/L305V/E296V-FVII, K316H/L305V/M298Q-FVII,
35 K316H/L305V/V158T-FVII, K316H/L305V/K337A/V158T-FVII,
K316H/L305V/K337A/M298Q-FVII, K316H/L305V/K337A/E296V-FVII,
K316H/L305V/K337A/V158D-FVII, K316H/L305V/V158D/M298Q-FVII,

K316H/L305V/V158D/E296V-FVII, K316H/L305V/V158T/M298Q-FVII,

K316H/L305V/V158T/E296V-FVII, K316H/L305V/E296V/M298Q-FVII,

K316H/L305V/V158D/E296V/M298Q-FVII, K316H/L305V/V158T/E296V/M298Q-FVII,

K316H/L305V/V158T/K337A/M298Q-FVII, K316H/L305V/V158T/E296V/K337A-FVII,

5   K316H/L305V/V158D/K337A/M298Q-FVII, K316H/L305V/V158D/E296V/K337A –FVII,

K316H/L305V/V158D/E296V/M298Q/K337A-FVII,

K316H/L305V/V158T/E296V/M298Q/K337A-FVII, K316Q/L305V/K337A-FVII,

K316Q/L305V/V158D-FVII, K316Q/L305V/E296V-FVII, K316Q/L305V/M298Q-FVII,

K316Q/L305V/V158T-FVII, K316Q/L305V/K337A/V158T-FVII,

10   K316Q/L305V/K337A/M298Q-FVII, K316Q/L305V/K337A/E296V-FVII,

K316Q/L305V/K337A/V158D-FVII, K316Q/L305V/V158D/M298Q-FVII,

K316Q/L305V/V158D/E296V-FVII, K316Q/L305V/V158T/M298Q-FVII,

K316Q/L305V/V158T/E296V-FVII, K316Q/L305V/E296V/M298Q-FVII,

K316Q/L305V/V158D/E296V/M298Q-FVII, K316Q/L305V/V158T/E296V/M298Q-FVII,

15   K316Q/L305V/V158T/K337A/M298Q-FVII, K316Q/L305V/V158T/E296V/K337A-FVII,

K316Q/L305V/V158D/K337A/M298Q-FVII, K316Q/L305V/V158D/E296V/K337A –FVII,

K316Q/L305V/V158D/E296V/M298Q/K337A-FVII,

K316Q/L305V/V158T/E296V/M298Q/K337A-FVII, F374Y/K337A-FVII, F374Y/V158D-FVII,

F374Y/E296V-FVII, F374Y/M298Q-FVII, F374Y/V158T-FVII, F374Y/S314E-FVII,

20   F374Y/L305V-FVII, F374Y/L305V/K337A-FVII, F374Y/L305V/V158D-FVII,

F374Y/L305V/E296V-FVII, F374Y/L305V/M298Q-FVII, F374Y/L305V/V158T-FVII,

F374Y/L305V/S314E-FVII, F374Y/K337A/S314E-FVII, F374Y/K337A/V158T-FVII,

F374Y/K337A/M298Q-FVII, F374Y/K337A/E296V-FVII, F374Y/K337A/V158D-FVII,

F374Y/V158D/S314E-FVII, F374Y/V158D/M298Q-FVII, F374Y/V158D/E296V-FVII,

25   F374Y/V158T/S314E-FVII, F374Y/V158T/M298Q-FVII, F374Y/V158T/E296V-FVII,

F374Y/E296V/S314E-FVII, F374Y/S314E/M298Q-FVII, F374Y/E296V/M298Q-FVII,

F374Y/L305V/K337A/V158D-FVII, F374Y/L305V/K337A/E296V-FVII,

F374Y/L305V/K337A/M298Q-FVII, F374Y/L305V/K337A/V158T-FVII,

F374Y/L305V/K337A/S314E-FVII, F374Y/L305V/V158D/E296V-FVII,

30   F374Y/L305V/V158D/M298Q-FVII, F374Y/L305V/V158D/S314E-FVII,

F374Y/L305V/E296V/M298Q-FVII, F374Y/L305V/E296V/V158T-FVII,

F374Y/L305V/E296V/S314E-FVII, F374Y/L305V/M298Q/V158T-FVII,

F374Y/L305V/M298Q/S314E-FVII, F374Y/L305V/V158T/S314E-FVII,

F374Y/K337A/S314E/V158T-FVII, F374Y/K337A/S314E/M298Q-FVII,

35   F374Y/K337A/S314E/E296V-FVII, F374Y/K337A/S314E/V158D-FVII,

F374Y/K337A/V158T/M298Q-FVII, F374Y/K337A/V158T/E296V-FVII,

F374Y/K337A/M298Q/E296V-FVII, F374Y/K337A/M298Q/V158D-FVII,

F374Y/K337A/E296V/V158D-FVII, F374Y/V158D/S314E/M298Q-FVII,

F374Y/V158D/S314E/E296V-FVII, F374Y/V158D/M298Q/E296V-FVII,

F374Y/V158T/S314E/E296V-FVII, F374Y/V158T/S314E/M298Q-FVII,

F374Y/V158T/M298Q/E296V-FVII, F374Y/E296V/S314E/M298Q-FVII,

5   F374Y/L305V/M298Q/K337A/S314E-FVII, F374Y/L305V/E296V/K337A/S314E-FVII,

F374Y/E296V/M298Q/K337A/S314E-FVII, F374Y/L305V/E296V/M298Q/K337A –FVII,

F374Y/L305V/E296V/M298Q/S314E-FVII, F374Y/V158D/E296V/M298Q/K337A-FVII,

F374Y/V158D/E296V/M298Q/S314E-FVII, F374Y/L305V/V158D/K337A/S314E-FVII,

F374Y/V158D/M298Q/K337A/S314E-FVII, F374Y/V158D/E296V/K337A/S314E-FVII,

10   F374Y/L305V/V158D/E296V/M298Q-FVII, F374Y/L305V/V158D/M298Q/K337A-FVII,

F374Y/L305V/V158D/E296V/K337A-FVII, F374Y/L305V/V158D/M298Q/S314E-FVII,

F374Y/L305V/V158D/E296V/S314E-FVII, F374Y/V158T/E296V/M298Q/K337A-FVII,

F374Y/V158T/E296V/M298Q/S314E-FVII, F374Y/L305V/V158T/K337A/S314E-FVII,

F374Y/V158T/M298Q/K337A/S314E-FVII, F374Y/V158T/E296V/K337A/S314E-FVII,

15   F374Y/L305V/V158T/E296V/M298Q-FVII, F374Y/L305V/V158T/M298Q/K337A-FVII,

F374Y/L305V/V158T/E296V/K337A-FVII, F374Y/L305V/V158T/M298Q/S314E-FVII,

F374Y/L305V/V158T/E296V/S314E-FVII, F374Y/E296V/M298Q/K337A/V158T/S314E-

FVII, F374Y/V158D/E296V/M298Q/K337A/S314E-FVII,

F374Y/L305V/V158D/E296V/M298Q/S314E-FVII,

20   F374Y/L305V/E296V/M298Q/V158T/S314E-FVII,

F374Y/L305V/E296V/M298Q/K337A/V158T-FVII,

F374Y/L305V/E296V/K337A/V158T/S314E-FVII,

F374Y/L305V/M298Q/K337A/V158T/S314E-FVII,

F374Y/L305V/V158D/E296V/M298Q/K337A-FVII,

25   F374Y/L305V/V158D/E296V/K337A/S314E-FVII,

F374Y/L305V/V158D/M298Q/K337A/S314E-FVII,

F374Y/L305V/E296V/M298Q/K337A/V158T/S314E-FVII,

F374Y/L305V/V158D/E296V/M298Q/K337A/S314E-FVII, S52A-Factor VII, S60A-Factor

VII; R152E-Factor VII, S344A-Factor VII, T106N-FVII, K143N/N145T-FVII, V253N-FVII,

30   R290N/A292T-FVII, G291N-FVII, R315N/V317T-FVII, K143N/N145T/R315N/V317T-FVII;

and FVII having substitutions, additions or deletions in the amino acid sequence from

233Thr to 240Asn; FVII having substitutions, additions or deletions in the amino acid se-

quence from 304Arg to 329Cys; and FVII having substitutions, additions or deletions in

the amino acid sequence from 153Ile to 223Arg.

35

The invention also relates to a method of preparing vitamin K-dependent proteins as

mentioned above.   The vitamin K-dependent proteins are preferably produced by

12

recombinant DNA techniques.   To this end, DNA sequences encoding the vitamin K-dependent proteins may be isolated by preparing a genomic or cDNA library and screening for DNA sequences coding for all or part of the protein by hybridization using synthetic oligonucleotide probes in accordance with standard techniques (cf. Sambrook et al.,

5   *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor Laboratory, Cold Spring Harbor, New York, 1989).   For the present purpose, the DNA sequence encoding the protein is preferably of human origin, i.e., derived from a human genomic DNA or cDNA library.

The invention also relates to a method of activating (i.e., turning on) a gene encoding a

10   vitamin K-dependent protein present in primary, secondary, or immortalized cells of vertebrate origin, which is normally not expressed in the cells or is not expressed at physiologically significant levels in the cells as obtained. Homologous recombination can be used to replace or disable the regulatory region normally associated with the gene in cells as obtained with a regulatory sequence which causes the gene to be expressed at

15   levels higher than evident in the corresponding nontransfected cell, or to display a pattern of regulation or induction that is different than evident in the corresponding nontransfected cell.   The invention, therefore, also relates to a method of preparing vitamin K-dependent proteins by turning on or activating an endogenous gene which encodes the vitamin K-dependent protein in transfected primary, secondary, or

20   immortalized cells.   Activation of endogenous genes may be performed as described in U.S. Patent No. 5,968,502.   The DNA sequences encoding the vitamin K-dependent proteins may also be prepared synthetically by established standard methods, e.g. the phosphoamidite method described by Beaucage and Caruthers, *Tetrahedron Letters* 22 (1981), 1859-1869, or the method described by Matthes et al., *EMBO Journal* 3 (1984),

25   801-805. According to the phosphoamidite method, oligonucleotides are synthesized, e.g. in an automatic DNA synthesizer, purified, annealed, ligated and cloned in suitable vectors.

The DNA sequences may also be prepared by polymerase chain reaction using specific primers, for instance as described in U.S. Patent No. 4,683,202, Saiki et al., *Science* 239

30   (1988), 487-491, or Sambrook et al., *supra.*

The DNA sequences encoding the vitamin K-dependent proteins are usually inserted into a recombinant vector which may be any vector, which may conveniently be subjected to recombinant DNA procedures, and the choice of vector will often depend on the host cell

35   into which it is to be introduced.   Thus, the vector may be an autonomously replicating vector, i.e. a vector, which exists as an extrachromosomal entity, the replication of which is independent of chromosomal replication, e.g. a plasmid.   Alternatively, the vector may

be one which, when introduced into a host cell, is integrated into the host cell genome and replicated together with the chromosome(s) into which it has been integrated.

The vector is preferably an expression vector in which the DNA sequence encoding the 5 vitamin K-dependent proteins is operably linked to additional segments required for transcription of the DNA. In general, the expression vector is derived from plasmid or viral DNA, or may contain elements of both. The term, "operably linked" indicates that the segments are arranged so that they function in concert for their intended purposes, e.g. transcription initiates in a promoter and proceeds through the DNA sequence coding for the 10 polypeptide.

The promoter may be any DNA sequence, which shows transcriptional activity in the host cell of choice and may be derived from genes encoding proteins either homologous or heterologous to the host cell.

15

Examples of suitable promoters for directing the transcription of the DNA encoding the vitamin K-dependent protein in mammalian cells are the SV40 promoter (Subramani et al., *Mol. Cell Biol.* 1 (1981), 854-864), the MT-1 (metallothionein gene) promoter (Palmiter et al., *Science* 222 (1983), 809-814), the CMV promoter (Boshart et al., Cell 41:521-530, 20 1985) or the adenovirus 2 major late promoter (Kaufman and Sharp, Mol. Cell. Biol, 2: 1304-1319, 1982).

An example of a suitable promoter for use in insect cells is the polyhedrin promoter (U.S. Patent No. 4,745,051; Vasuvedan et al., *FEBS Lett.* 311, (1992) 7-11), the P10 promoter 25 (J.M. Vlak et al., *J. Gen. Virology* 69, 1988, pp. 765-776), the *Autographa californica* polyhedrosis virus basic protein promoter (EP 397 485), the baculovirus immediate early gene 1 promoter (U.S. Patent Nos.5,155,037 and 5,162,222), or the baculovirus 39K delayed-early gene promoter (U.S. Patent Nos. 5,155,037 and 5,162,222).

30 Examples of suitable promoters for use in yeast host cells include promoters from yeast glycolytic genes (Hitzeman et al., *J. Biol. Chem.* 255 (1980), 12073-12080; Alber and Kawasaki, *J. Mol. Appl. Gen.* 1 (1982), 419-434) or alcohol dehydrogenase genes (Young et al., in *Genetic Engineering of Microorganisms for Chemicals* (Hollaender et al, eds.), Plenum Press, New York, 1982), or the TPI1 (U.S. Patent No. 4,599,311) or ADH2-4c (Russell et al., 35 *Nature* 304 (1983), 652-654) promoters or the nmt1 promoter (Maundrell-K, J Biol Chem. 1990 Jul 5;265(19):10857-64). Promoters used in mammalian cells also function in *S. pombe*.

14

Examples of suitable promoters for use in filamentous fungus host cells are, for instance, the ADH3 promoter (McKnight et al., *The EMBO J.* 4 (1985), 2093-2099) or the tpiA promoter. Examples of other useful promoters are those derived from the gene encoding *A. oryzae* TAKA amylase, *Rhizomucor miehei* aspartic proteinase, *A. niger* or *A. awamori* glu-
5   coamylase (gluA), *Rhizomucor miehei* lipase, *A. oryzae* alkaline protease, *A. oryzae* triose phosphate isomerase or *A. nidulans* acetamidase. Preferred are the TAKA-amylase and gluA promoters. Suitable promoters are mentioned in, e.g. EP 238 023 and EP 383 779.

10 The DNA sequences encoding the vitamin K-dependent proteins may also, if necessary, be operably connected to a suitable terminator, such as the human growth hormone terminator (Palmiter et al., *Science* 222, 1983, pp. 809-814) or the TPI1 (Alber and Kawasaki, *J. Mol. Appl. Gen.* 1, 1982, pp. 419-434) or ADH3 (McKnight et al., *The EMBO J.* 4, 1985, pp. 2093-2099) terminators or the nmt1 terminator (Maundrell-K, J Biol Chem.
15 1990 Jul 5;265(19):10857-64). The vector may also contain a set of RNA splice sites located downstream from the promoter and upstream from the insertion site for the FVII sequence itself. Preferred RNA splice sites may be obtained from adenovirus and/or immunoglobulin genes. Also contained in the expression vectors is a polyadenylation signal located downstream of the insertion site. Particularly preferred polyadenylation
20 signals include the early or late polyadenylation signal from SV40 (Kaufman and Sharp, ibid.), the polyadenylation signal from the adenovirus 5 Elb region, the human growth hormone gene terminator (DeNoto et al. *Nuc. Acids Res.* 9:3719-3730, 1981), or the polyadenylation signal from the human FVII gene or the bovine FVII gene. The expression vectors may also include a noncoding viral leader sequence, such as the
25 adenovirus 2 tripartite leader, located between the promoter and the gene of interest; and enhancer sequences, such as the SV40 enhancer.

The recombinant vector may further comprise a DNA sequence enabling the vector to repli-cate in the host cell in question. An example of such a sequence (when the host cell is a
30 mammalian cell) is the SV40 origin of replication.

When the host cell is a yeast cell, suitable sequences enabling the vector to replicate are the yeast plasmid 2μ replication genes REP 1-3 and origin of replication, or ARSH4/CEN6. *Schizosaccharomyces pombe ars1* (Heyer-WD et al., 1996 Mol. Cell. Biol.6, 80-89.
35

The vector may also comprise a selectable marker, e.g. a gene the product of which complements a defect in the host cell, such as the gene coding for dihydrofolate reductase

(DHFR) or the *Schizosaccharomyces pombe* TPI gene (described by P.R. Russell, *Gene* 40, 1985, pp. 125-130), *Saccahromyces cerevisiae* LEU2, HIS3, URA3 or *Schizosachharomyces pombe* ade6 or ura4, or one which confers resistance to a drug, e.g. ampicillin, kanamycin, tetracyclin, chloramphenicol, neomycin, or hygromycin. For filamentous fungi, selectable
5   markers include amdS, pyrG, argB, niaD or sC.

To direct the vitamin K-dependent proteins of the present invention into the secretory pathway of the host cells, a secretory signal sequence (also known as a leader sequence, prepro sequence or pre sequence) may be provided in the recombinant vector. The
10   secretory signal sequence is joined to the DNA sequences encoding the vitamin K-dependent proteins in the correct reading frame. Secretory signal sequences are commonly positioned 5' to the DNA sequence encoding the peptide. The secretory signal sequence may be that, normally associated with the protein or may be from a gene encoding another secreted protein.

15

For secretion from yeast cells, the secretory signal sequence may encode any signal peptide, which ensures efficient direction of the expressed vitamin K-dependent proteins into the secretory pathway of the cell. The signal peptide may be naturally-occurring signal peptide, or a functional part thereof, or it may be a synthetic peptide. Suitable signal
20   peptides have been found to be the α-factor signal peptide (cf. U.S. Patent No. 4,870,008), the signal peptide of mouse salivary amylase (cf. O. Hagenbuchle et al., *Nature* 289, 1981, pp. 643-646), a modified carboxypeptidase signal peptide (cf. L.A. Valls et al., *Cell* 48, 1987, pp. 887-897), the yeast BAR1 signal peptide (cf. WO 87/02670), or the yeast aspartic protease 3 (YAP3) signal peptide (cf. M. Egel-Mitani et al., *Yeast* 6, 1990, pp. 127-
25   137).

For efficient secretion in yeast, a sequence encoding a leader peptide may also be inserted downstream of the signal sequence and upstream of the DNA sequence encoding the vitamin K-dependent proteins. The function of the leader peptide is to allow the expressed
30   peptide to be directed from the endoplasmic reticulum to the Golgi apparatus and further to a secretory vesicle for secretion into the culture medium (i.e. exportation of the vitamin K-dependent proteins across the cell wall or at least through the cellular membrane into the periplasmic space of the yeast cell). The leader peptide may be the yeast α-factor leader (the use of which is described in e.g. U.S. Patent Nos. 4,546,082 and 4,870,008, EP 16 201,
35   EP 123 294, EP 123 544 and EP 163 529). Alternatively, the leader peptide may be a synthetic leader peptide, which is to say a leader peptide not found in nature. Synthetic

16

leader peptides may, for instance, be constructed as described in WO 89/02463 or WO 92/11378.

For use in filamentous fungi, the signal peptide may conveniently be derived from a gene
5   encoding an *Aspergillus* sp. amylase or glucoamylase, a gene encoding a *Rhizomucor miehei* lipase or protease or a *Humicola lanuginosa* lipase. The signal peptide is preferably derived from a gene encoding *A. oryzae* TAKA amylase, *A. niger* acid-stable amylase, or *A. niger* glucoamylase. Suitable signal peptides are disclosed in, e.g. EP 238 023 and EP 215 594.
10

For use in insect cells, the signal peptide may conveniently be derived from an insect gene (cf. WO 90/05783), such as the lepidopteran *Manduca sexta* adipokinetic hormone precursor signal peptide (cf. US 5,023,328).

15   The procedures used to ligate the DNA sequences coding for the vitamin K-dependent proteins, the promoter and optionally the terminator and/or secretory signal sequence, respectively, and to insert them into suitable vectors containing the information necessary for replication, are well known to persons skilled in the art (cf., for instance, Sambrook et al., *Molecular Cloning: A Laboratory Manual*, Cold Spring Harbor, New York, 1989).
20

Methods of transfecting mammalian cells and expressing DNA sequences introduced in the cells are described in e.g. Kaufman and Sharp, *J. Mol. Biol.* 159 (1982), 601-621; Southern and Berg, *J. Mol. Appl. Genet.* 1 (1982), 327-341; Loyter et al., *Proc. Natl. Acad. Sci. USA* 79 (1982), 42 -426; Wigler et al., *Cell* 14 (1978), 725; Corsaro and Pearson, *Somatic Cell*
25   *Genetics* 7 (1981), 603, Graham and van der Eb, *Virology* 52 (1973), 456; and Neumann et al., *EMBO J.* 1 (1982), 841-845.

Selectable markers may be introduced into the cell on a separate plasmid at the same time as the gene of interest, or they may be introduced on the same plasmid. If on the
30   same plasmid, the selectable marker and the gene of interest may be under the control of different promoters or the same promoter, the latter arrangement producing a dicistronic message. Constructs of this type are known in the art (for example, Levinson and Simonsen, U.S. Pat. No. 4,713,339). It may also be advantageous to add additional DNA, known as "carrier DNA," to the mixture that is introduced into the cells.
35

After the cells have taken up the DNA, they are grown in an appropriate growth medium, typically 1-2 days, to begin expressing the gene of interest. As used herein the term

17

"appropriate growth medium" means a medium containing nutrients and other compo-
nents required for the growth of cells and the expression of the vitamin K-dependent pro-
tein of interest. Media generally include a carbon source, a nitrogen source, essential
amino acids, essential sugars, vitamins, salts, phospholipids, protein and growth factors.
5   For production of gamma-carboxylated proteins, the medium will contain vitamin K, pref-
erably at a concentration of about 0.1 µg/ml to about 5 µg/ml. Drug selection is then
applied to select for the growth of cells that are expressing the selectable marker in a
stable fashion. For cells that have been transfected with an amplifiable selectable marker
the drug concentration may be increased to select for an increased copy number of the
10   cloned sequences, thereby increasing expression levels. Clones of stably transfected
cells are then screened for expression of the vitamin K-dependent protein of interest.

The host cell into which the DNA sequences encoding the vitamin K-dependent proteins is
introduced may be any cell, which is capable of producing the posttranslational modified vi-
15   tamin K-dependent proteins and includes yeast, fungi and higher eucaryotic cells.

Examples of mammalian cell lines for use in the present invention are the COS-1 (ATCC
CRL 1650), baby hamster kidney (BHK) and 293 (ATCC CRL 1573; Graham et al., *J. Gen.
Virol.* 36:59-72, 1977) cell lines. A preferred BHK cell line is the tk.sup.- ts13 BHK cell
20   line (Waechter and Baserga, *Proc. Natl. Acad. Sci. USA* 79:1106-1110, 1982, incorpo-
rated herein by reference), hereinafter referred to as BHK 570 cells. The BHK 570 cell
line has been deposited with the American Type Culture Collection, 12301 Parklawn Dr.,
Rockville, Md. 20852, under ATCC accession number CRL 10314. A tk.sup.- ts13 BHK
cell line is also available from the ATCC under accession number CRL 1632. In addition,
25   a number of other cell lines may be used within the present invention, including Rat Hep
I (Rat hepatoma; ATCC CRL 1600), Rat Hep II (Rat hepatoma; ATCC CRL 1548), TCMK
(ATCC CCL 139), Human lung (ATCC HB 8065), NCTC 1469 (ATCC CCL 9.1), CHO (ATCC
CCL 61) and DUKX cells (Urlaub and Chasin, *Proc. Natl. Acad. Sci. USA* 77:4216-4220,
1980). Also useful are 3T3 cells, Namalwa cells, myelomas and fusions of myelomas with
30   other cells, PER.C6® cell lines (Crucell N.V., The Netherlands), and HKB11 cell lines (Cho
et al. *J. Biomed Sci.* 2002, 9:631-638).

Examples of suitable yeasts cells include cells of *Saccharomyces* spp. or *Schizosaccharomy-
ces* spp., in particular strains of *Saccharomyces cerevisiae, Saccharomyces kluyveri* or
35   *Schizosaccharomyces pombe*. Methods for transforming yeast cells with heterologous DNA
and producing heterologous polypeptides there from are described, e.g. in U.S. Patent Nos.
4,599,311, 4,931,373, 4,870,008, 5,037,743, and 4,845,075, all of which are hereby incor-

porated by reference. Transformed cells are selected by a phenotype determined by a se-
lectable marker, commonly drug resistance or the ability to grow in the absence of a par-
ticular nutrient, e.g. leucine. A preferred vector for use in yeast is the POT1 vector disclosed
in U.S. Patent No. 4,931,373. Additional examples of possible vectors include pRS-series of

5   shuttle vectors or p425, and for *Schizosaccharomyces pombe*: the pREP series of vectors.
The DNA sequences encoding the vitamin K-dependent proteins may be preceded by a sig-
nal sequence and optionally a leader sequence, e.g. as described above. Further examples
of suitable yeast cells are strains of *Kluyveromyces*, such as *K. lactis*, *Hansenula*, e.g. *H.
polymorpha*, or *Pichia*, e.g. *P. pastoris* (cf. Gleeson et al., *J. Gen. Microbiol.* 132, 1986, pp.

10   3459-3465; U.S. Patent No. 4,882,279).

Examples of other fungal cells are cells of filamentous fungi, e.g. *Aspergillus* spp.,
Neurospora spp., *Fusarium* spp. or *Trichoderma* spp., in particular strains of *A. oryzae*, *A.
nidulans* or *A. niger*. The use of *Aspergillus* spp. for the expression of proteins is described

15   in, e.g., EP 272 277, EP 238 023, and EP 184 438. The transformation of *F. oxysporum*
may, for instance, be carried out as described by Malardier et al., 1989, *Gene* 78: 147-156.
The transformation of *Trichoderma* spp. may be performed for instance as described in EP
244 234.

20   When a filamentous fungus is used as the host cell, it may be transformed with the DNA
construct of the invention, conveniently by integrating the DNA construct in the host
chromosome to obtain a recombinant host cell. This integration is generally considered to
be an advantage as the DNA sequence is more likely to be stably maintained in the cell.
Integration of the DNA constructs into the host chromosome may be performed according

25   to conventional methods, e.g. by homologous or heterologous recombination.

When *Schizosaccharomyces pombe* is used as the host cell, it may be transformed with the
DNA construct of the invention, conveniently by integrating the DNA construct in the host
chromosome to obtain a recombinant host cell. This integration is generally considered to

30   be an advantage as the DNA sequence is more likely to be stably maintained in the cell.
Integration of the DNA constructs into the host chromosome may be performed according
to conventional methods, e.g. by homologous or heterologous recombination.

Transformation of insect cells and production of heterologous polypeptides therein may be

35   performed as described in U.S. Patent Nos. 4,745,051, 4,879,236, 5,155,037, 5,162,222;
and EP 397,485) all of which are incorporated herein by reference. The insect cell line used
as the host may suitably be a *Lepidoptera* cell line, such as *Spodoptera frugiperda* cells or

19

Trichoplusia ni cells (cf. U.S. Patent No. 5,077,214). Culture conditions may suitably be as described in, for instance, WO 89/01029 or WO 89/01028, or any of the aforementioned references.

5   The transformed or transfected host cell described above is then cultured in a suitable nutrient medium under conditions permitting expression of the vitamin K-dependent protein after which all or part of the resulting peptide may be recovered from the culture. The medium used to culture the cells may be any conventional medium suitable for growing the host cells, such as minimal or complex media containing appropriate supplements. Suitable

10   media are available from commercial suppliers or may be prepared according to published recipes (e.g. in catalogues of the American Type Culture Collection). The vitamin K-dependent protein produced by the cells may then be recovered from the culture medium by conventional procedures including separating the host cells from the medium by centrifugation or filtration, precipitating the proteinaqueous components of the supernatant

15   or filtrate by means of a salt, e.g. ammonium sulphate, purification by a variety of chromatographic procedures, e.g. ion exchange chromatography, gelfiltration chromatography, affinity chromatography, or the like, dependent on the type of polypeptide in question.

20   For the preparation of recombinant human FVII or variants thereof, a cloned wild-type FVII DNA sequence is used. This sequence may be modified to encode the desired FVII protein or variants thereof. The sequence is then inserted into an expression vector, which is in turn transformed or transfected into host cells. Higher eucaryotic cells, in particular cultured mammalian cells, are preferred as host cells. The complete nucleotide

25   and amino acid sequences for human FVII are known. See U.S. Pat. No. 4,784,950, which is incorporated herein by reference, wherein the cloning and expression of recombinant human FVII is described. The bovine FVII sequence is described in Takeya et al., *J. Biol. Chem.*, 263:14868-14872 (1988), which is incorporated by reference herein.

30   The amino acid sequence alterations may be accomplished by a variety of techniques. Modification of the DNA sequence may be by site-specific mutagenesis. Techniques for site-specific mutagenesis are well known in the art and are described by, for example, Zoller and Smith (*DNA* 3:479-488, 1984). Thus, using the nucleotide and amino acid sequences of FVII, one may introduce the alterations of choice.

35

DNA sequences for use within the present invention will typically encode a pre-pro peptide at the amino-terminus of the FVII protein to obtain proper post-translational proc-

essing (e.g. gamma-carboxylation of glutamic acid residues) and secretion from the host cell. The pre-pro peptide may be that of FVII or another vitamin K-dependent plasma protein, such as factor IX, factor X, prothrombin, protein C or protein S. As will be ap-preciated by those skilled in the art, additional modifications can be made in the amino

5   acid sequence of FVII where those modifications do not significantly impair the ability of the protein to act as a coagulation factor. For example, FVII in the catalytic triad can also be modified in the activation cleavage site to inhibit the conversion of zymogen FVII into its activated two-chain form, as generally described in U.S. Patent No. 5,288,629, incorporated herein by reference.

10

Within the present invention, transgenic animal technology may be employed to produce the vitamin K-dependent protein. It is preferred to produce the proteins within the mammary glands of a host female mammal. Expression in the mammary gland and sub-sequent secretion of the protein of interest into the milk overcomes many difficulties en-

15   countered in isolating proteins from other sources. Milk is readily collected, available in large quantities, and well characterized biochemically. Furthermore, the major milk pro-teins are present in milk at high concentrations (typically from about 1 to 15 g/l). From a commercial point of view, it is clearly preferable to use as the host a species that has a large milk yield. While smaller animals such as mice and rats can be used (and are pre-

20   ferred at the proof of principle stage), within the present invention it is preferred to use livestock mammals including, but not limited to, pigs, goats, sheep and cattle. Sheep are particularly preferred due to such factors as the previous history of transgenesis in this species, milk yield, cost and the ready availability of equipment for collecting sheep milk. See WIPO Publication WO 88/00239 for a comparison of factors influencing the choice of

25   host species. It is generally desirable to select a breed of host animal that has been bred for dairy use, such as East Friesland sheep, or to introduce dairy stock by breeding of the transgenic line at a later date.

To obtain expression in the mammary gland, a transcription promoter from a milk protein

30   gene is used. Milk protein genes include those genes encoding caseins (see U.S. Patent No. 5,304,489, incorporated herein by reference), beta-lactoglobulin, a-lactalbumin, and whey acidic protein. The beta-lactoglobulin (BLG) promoter is preferred. In the case of the ovine beta-lactoglobulin gene, a region of at least the proximal 406 bp of 5' flanking sequence of the gene will generally be used, although larger portions of the 5' flanking

35   sequence, up to about 5 kbp, are preferred, such as about 4.25 kbp DNA segment en-compassing the 5' flanking promoter and non-coding portion of the beta-lactoglobulin

21

gene. See Whitelaw et al., *Biochem J.* 286: 31-39 (1992). Similar fragments of pro-
moter DNA from other species are also suitable.

Other regions of the beta-lactoglobulin gene may also be incorporated in constructs, as
5   may genomic regions of the gene to be expressed. It is generally accepted in the art that
constructs lacking introns, for example, express poorly in comparison with those that
contain such DNA sequences (see Brinster et al., *Proc. Natl. Acad. Sci. USA* 85: 836-840
(1988); Palmiter et al., *Proc. Natl. Acad. Sci. USA* 88: 478-482 (1991); Whitelaw et al.,
Transgenic Res. 1: 3-13 (1991); WO 89/01343; and WO 91/02318, each of which is in-
10   corporated herein by reference). In this regard, it is generally preferred, where possible,
to use genomic sequences containing all or some of the native introns of a gene encoding
the protein or polypeptide of interest, thus the further inclusion of at least some introns
from, e.g, the beta-lactoglobulin gene, is preferred. One such region is a DNA segment
which provides for intron splicing and RNA polyadenylation from the 3' non-coding region
15   of the ovine beta-lactoglobulin gene. When substituted for the natural 3' non-coding se-
quences of a gene, this ovine beta-lactoglobulin segment can both enhance and stabilize
expression levels of the protein or polypeptide of interest. Within other embodiments,
the region surrounding the initiation ATG of the sequence encoding the vitamin K-
dependent protein is replaced with corresponding sequences from a milk specific protein
20   gene. Such replacement provides a putative tissue-specific initiation environment to en-
hance expression.

For expression of a vitamin K-dependent protein in transgenic animals, a DNA segment
encoding the vitamin K-dependent protein is operably linked to additional DNA segments
25   required for its expression to produce expression units. Such additional segments in-
clude the above-mentioned promoter, as well as sequences which provide for termination
of transcription and polyadenylation of mRNA. The expression units will further include a
DNA segment encoding a secretory signal sequence operably linked to the segment en-
coding the vitamin K-dependent protein. The secretory signal sequence may be a native
30   secretory signal sequence of the vitamin K-dependent protein or may be that of another
protein, such as a milk protein. See, for example, von Heinje, *Nuc. Acids Res.* 14: 4683-
4690 (1986); and Meade et al., U.S. Patent No. 4,873,316, which are incorporated herein
by reference.

35   Construction of expression units for use in transgenic animals is conveniently carried out
by inserting a sequence encoding the vitamin K-dependent protein into a plasmid or
phage vector containing the additional DNA segments, although the expression unit may

22

be constructed by essentially any sequence of ligations. It is particularly convenient to provide a vector containing a DNA segment encoding a milk protein and to replace the coding sequence for the milk protein with that of the vitamin K-dependent protein, thereby creating a gene fusion that includes the expression control sequences of the milk

5   protein gene. Cloning of the expression units in plasmids or other vectors facilitates the amplification of the vitamin K-dependent protein. Amplification is conveniently carried out in bacterial (e.g. *E. coli*) host cells, thus the vectors will typically include an origin of replication and a selectable marker functional in bacterial host cells.

10   The expression unit is then introduced into fertilized eggs (including early-stage em-bryos) of the chosen host species. Introduction of heterologous DNA can be accomplished by one of several routes, including microinjection (e.g. U.S. Patent No. 4,873,191), ret-roviral infection (Jaenisch, *Science* 240: 1468-1474 (1988)) or site-directed integration using embryonic stem (ES) cells (reviewed by Bradley et al., *Bio/Technology* 10: 534-539

15   (1992)). The eggs are then implanted into the oviducts or uteri of pseudopregnant fe-males and allowed to develop to term. Offspring carrying the introduced DNA in their germ line can pass the DNA on to their progeny in the normal, Mendelian fashion, allow-ing the development of transgenic herds.

20   General procedures for producing transgenic animals are known in the art. See, for ex-ample, Hogan et al., Manipulating the Mouse *Embryo: A Laboratory Manual*, Cold Spring Harbor Laboratory, 1986; Simons et al., *Bio/Technology* 6: 179-183 (1988); Wall et al., *Biol. Reprod.* 32: 645-651 (1985); Buhler et al., *Bio/Technology* 8: 140-143 (1990); Ebert et al., *Bio/Technology* 9: 835-838 (1991); Krimpenfort et al., *Bio/Technology* 9:

25   844-847 (1991); Wall et al., *J. Cell. Biochem.* 49: 113-120 (1992); U.S. Patent Nos. 4,873,191 and 4,873,316; WIPO publications WO 88/00239, WO 90/05188, WO 92/11757; and GB 87/00458, which are incorporated herein by reference. Techniques for introducing foreign DNA sequences into mammals and their germ cells were originally developed in the mouse. See, e.g., Gordon et al., *Proc. Natl. Acad. Sci. USA* 77: 7380-

30   7384 (1980); Gordon and Ruddle, *Science* 214: 1244-1246 (1981); Palmiter and Brin-ster, *Cell* 41: 343-345 (1985); Brinster et al., *Proc. Natl. Acad. Sci. USA* 82: 4438-4442 (1985); and Hogan et al. (ibid.). These techniques were subsequently adapted for use with larger animals, including livestock species (see e.g., WIPO publications WO 88/00239, WO 90/05188, and WO 92/11757; and Simons et al., *Bio/Technology* 6: 179-

35   183 (1988). To summarize, in the most efficient route used to date in the generation of transgenic mice or livestock, several hundred linear molecules of the DNA of interest are injected into one of the pro-nuclei of a fertilized egg according to established techniques.

Injection of DNA into the cytoplasm of a zygote can also be employed. Production in transgenic plants may also be employed. Expression may be generalized or directed to a particular organ, such as a tuber. See, Hiatt, *Nature* 344:469-479 (1990); Edelbaum et al., *J. Interferon Res.* 12:449-453 (1992); Sijmons et al., *Bio/Technology* 8:217-221 (1990); and European Patent Office Publication EP 255,378.

FVII produced according to the present invention may be purified by affinity chromatography on an anti-FVII antibody column. It is preferred that the immunoadsorption column comprise a high-specificity monoclonal antibody. The use of calcium-dependent monoclonal antibodies, as described by Wakabayashi et al., *J. Biol. Chem.*, 261:11097-11108, (1986) and Thim et al., *Biochem.* 27: 7785-7793, (1988), incorporated by reference herein, is particularly preferred. Additional purification may be achieved by conventional chemical purification means, such as high performance liquid chromatography. Other methods of purification, including barium citrate precipitation, are known in the art, and may be applied to the purification of the FVII described herein (see, generally, Scopes, R., Protein Purification, Springer-Verlag, N.Y., 1982). Substantially pure FVII of at least about 90 to 95% homogeneity is preferred, and 98 to 99% or more homogeneity most preferred, for pharmaceutical uses. Once purified, partially or to homogeneity as desired, the FVII may then be used therapeutically.

Conversion of single-chain FVII to active two-chain FVIIa may be achieved using factor XIIa as described by Hedner and Kisiel (1983, *J. Clin. Invest.* 71: 1836-1841), or with other proteases having trypsin-like specificity (Kisiel and Fujikawa, Behring Inst. Mitt. 73: 29-42, 1983). Alternatively, FVII may be activated by passing it through an ion-exchange chromatography column, such as mono Q.RTM. (Pharmacia Fire Chemicals) or the like (Bjoern et al., 1986, Research Disclosures 269:564-565). The FVII molecules of the present invention and pharmaceutical compositions thereof are particularly useful for administration to humans to treat a variety of conditions involving intravascular coagulation.

Vitamin K-dependent proteins of the present invention can be used to treat certain types of *hemophilia*. *Hemophilia* A is characterized by the absence of active factor VIII, factor VIIIa, or the presence of inhibitors to factor VIII. *Hemophilia* B is characterized by the absence of active factor IX, factor IXa. FVII deficiency, although rare, responds well to factor VII administration (Bauer, K. A., 1996, *Haemostasis*, 26:155-158, suppl. 1). Factor VIII replacement therapy is limited due to development of high-titer inhibitory factor VIII antibodies in some *patients*. Alternatively, FVIIa can be used in the treatment of

24

hemophilia A and B. Factor IXa and factor VIIIa activate factor X. Factor VIIa eliminates the need for factors IX and VIII by activating factor X directly, and can overcome the problems of factor IX and VIII deficiencies with few immunological consequences.

5   Other features of the invention will become apparent in the course of the following de-scriptions of exemplary embodiments that are given for illustration of the invention and are not intended to be limiting thereof.

10   EXAMPLES

General methods:

Activity of vitamin K-dependent coagulation factors are normally assessed by a person 15   skilled in the art, using assays such as Activated Partial Thromboplastin Time (APTT) or Prothrombin Time (PT) assay and an automated clot analyzer (e.g. ACL 9000, Instrumen-tation Laboratory, Lexington, MA, USA) as per manufacturer's instructions. A complete procedure for assaying FVII activity is described in, e.g., WO 92/15686 and Persson et al. (J Biol Chem 276: 29195-9, 2001).

20

Antigen levels in media samples or purified protein samples can be assessed by ELISA techniques known to a person skilled in the art. Examples of these are FIX and FVII spe-cific ELISA tests commercially available (e.g. Enzyme Research, South Bend, IN, USA; American Diagnostica, Stamford, CT, USA).

25

Restriction enzymes were purchased from New England Biolabs.

Example 1: Cloning of human VKORC1 cDNA
30

The human Vitamin K epoxide reductase was cloned by PCR on human liver (Clontech, Marathon ready cDNA) using the 'Herculase' polymerase from Stratagene and the oli-gonucleotide primers:

        VKOR-3: 5'-CAC CAG ATC TAC CAT GGG CAG CAC CTG GGG GAG-3' (N-term, 35   Bgl II site) (SEQ ID NO:15);

        VKOR-4: 5'-AAA AGC TTC AGT GAT GGT GAT GAT GGT GCC TCT TAG CCT TGC CCT GGG G-3' (C-term, 6XHis and a Hin dIII site) (SEQ ID NO:16).

The resulting 500 bp PCR fragment was inserted into pCR-Blunt (Invitrogen) and sequenced. The sequence was identical to the coding part of the published VKORC1 (NCBI accession no. NM_02006) extended with a C-terminal His-tag.

5   Example 2: Cloning of human gamma-carboxylase cDNA

Total RNA was isolated from HEK293 cells (ATCC CRL-1573) using Promega nucleic acid purification kit "SV Total RNA Isolation System" as per manufacturer's instructions. A total of 150 micrograms RNA was isolated. Reverse transcription was employed to generate

10   cDNA from the isolated RNA using SuperScript (Invitrogen, Carlsbad CA, USA) as per manufacturer's instructions. The complete cDNA for the gamma-carboxylase was amplified using a 1:1 mixture of BioTaq and Bio-X-Act (DNA Technology, Aarhus, Denmark). The PCR reaction was analyzed using a 1% agarose gel. A DNA band with the correct size was excised from the gel and purified. The cDNA was cloned into the pBluescriptKS+ vec-

15   tor for further analysis.

Clones from the PCR reaction were analyzed by automated sequencing and compared to the published sequence for the gamma-carboxylase (NCBI accession no. NM_000821). Due to errors in the sequences of the clones, a correct cDNA clone was assembled by

20   ligating three fragments from individual clones into pBluescriptKS+. The resulting plasmid was digested with BamHI and XbaI, and the complete, sequence verified gamma-carboxylase cDNA was isolated by gel purification. Using the same restriction enzymes, followed by de-phosphorylation, the pcDNA3.1+ vector (Invitrogen, Carlsbad, CA, USA) was opened, and the carboxylase cDNA ligated into the vector for expression studies.

25   This expression plasmid was named pLN438. The sequence for pLN438 is listed in SEQ ID NO:1. A corresponding construct in pcDNA3.1+/hygro (Invitrogen) was generated using the same restriction enzymes. This construct was named pLN439. The sequence for pLN439 is listed in SEQ ID NO:2.

30   Example 3: Coexpression of Vitamin-K 2,3 epoxide reductase and γ-Carboxylase in CHO-Dukx B11 cells overexpressing γ-carboxylation deficient Factor IX

The gene coding for the Vitamin K 2,3 epoxide reductase was subcloned into the expression vector pcDNA3.1(+)-Hyg (Invitrogen). The Vitamin-K 2,3 epoxide-reductase gene

35   was isolated by digesting the vector pSX765 (see Example 1, above) with BglII and SpeI. The resulting ~550 bp fragment was purified by gel electrophoresis and ligated into a pcDNA3.1(+)-Hyg vector digested with BamHI and XbaI. The orientation and nature of

26

the insert was confirmed by cutting the resulting plasmid with the restriction enzyme NcoI. The resulting plasmid was named pTS86-Hyg (see FIG. 1).

CHO Dukx-B11 cells were transfected with the expression plasmid pTS75 (see FIG 2),
5   harboring an intact FIX cDNA sequence and a DHFR gene. Stable FIX expressing cells were selected in MEM alpha minus medium (Invitrogen, Carlsbad, CA, USA) and subsequently amplified by the addition of Methotrexate (MTX) essentially as described by Randal J. Kaufman (Expression, Purification, and Characterization of Recombinant Gamma-Carboxylated Factor IX Synthesized in Chinese Hamster Ovary Cells, *J.B.C.* 261,
10   9622 (1986)).

A number of single cell clones of cells amplified to 50 nM MTX were selected and assayed for FIX expression using an FIX ELISA. FIX clot activity measurements were subsequently performed on supernatants from high yielding clones.

15

To test for increased gamma-carboxylation as a result of co-expression of gamma-carboxylase and VKOR, clones with high specific productivity but with low specific FIX clot activity were selected for transfection. Transfections were performed in triplicate with the expression plasmids pTS86 (see above) and pLN438 (see Example 2, above) containing
20   the Vitamin K 2,3 epoxide reductase gene and the γ-carboxylase gene respectively. Cells were selected on 500 µg/ml Geneticin (Gibco) and 500 µg/ml Hygromycin (Invitrogen) for two weeks.

Following the two weeks of selection, FIX activity can be measured in the cell pools. Single cell clones can be generated on the cell pools exhibiting increased FIX clot activity by
25   limiting dilution cloning. Clones with high specific productivity and with high specific activity, as judged by ELISA and ACL9000 analysis, can then be isolated demonstrating increased carboxylation by co-expression of the Vitamin K 2,3 epoxide reductase gene.

Example 4: Expression of γ-carboxylated FVII in insect cells.
30

The His-tagged VKORC1 gene was cut with Bgl II and Hin dIII, isolated and inserted into Bam HI – Hin dIII cut pBlueBac4.5 (Invitrogen) for expression in the Baculovirus system, as per manufacturer's instructions (Invitrogen Bac-N-Blue™ Transfection Kit Manual), yielding expression vector pSX766. The human γ-carboxylase from pLN438 was provided
35   with a 5′ Bam HI site and an N-terminal FLAG-tag (MDYKDDDDK) (SEQ ID NO:17) and with a 3′ Sal I site and a C-terminal HPC4-tag (EDQVDPRLIDGK) (SEQ ID NO:18). The

27

gene was cut with Bam HI and Sal I and inserted into pBlueBac4.5 cut with the same enzymes, yielding the expression vector pSX691. The human FVII gene was provided with a 5' Bam HI site and a 3' Hin dIII site and inserted into pBlueBac 4.5 cut with the same enzymes, yielding the expression vector pSX751.

5

The three plasmids (pSX766, pSX691, and pSX751) can then be co-transfected into *Spodoptera frugiperda* (sf9) cells together with Bac-N-Blue Linear Baculovirus DNA (Invitrogen). Media samples can be harvested and expression of gamma-carboxylated FVII can be demonstrated by comparing antigen levels using ELISA with activity of the FVII anti-
10   gen using clot analysis.

Example 5: Expression of γ-carboxylated FVII in yeast.

15   Human FVII can be expressed in *Saccharomyces cerevisiae* carrying an 'HSA/MF(alpha)-1 fusion leader' of 24 amino acids in order to achieve secretion into the culture medium.

The in-house developed 'p425' expression vector (derived from plasmids described by Mumberg et al., 1994, Nucleic Acids Research), can be used to express FVII. A FVII ex-
20   pression vector has been constructed by ligating a FVII BamHI+EcoRV fragment from the in-house developed FVII vector pTS8 (FVII cDNA in pcDNA3.1(+) (Invitrogen)) with BamHI+EcoRV digested and dephosphorylated 'pBluescriptSK(+)' using T4 DNA ligase (New England Biolabs)..A HSA/MF(alpha)1 signal sequence was introduced by ligating annealed oligonucleotides encoding the signal sequence
25   (ggatccaccatgaaatgggtttctttttatttctttgttgttttttgttttcttctgcttattctagatctttggataaaagagcagtcttc gtaacccaggaggaagcccacggcgtcctgcaccggcgccggcgcgccaacgcgt (SEQ ID NO: 12))
with BamHI-MluI digested 'FVII-pBluescriptSK(+)' using T4 DNA ligase (New England Biolabs). BamHI+EcoRV restricted FVII, including signal-sequence-encoding sequence, was ligated with BamHI+SmaI digested and dephosphorylated 'p425(delta XhoI)' using
30   1U T4 DNA ligase (New England Biolabs). The resulting plasmid was termed 'FVII HSA/MF(alpha)1 signal p425' (see FIG. 3). The sequence of plasmid 'FVII HSA/MF(alpha)1 signal p425' is listed in SEQ ID NO:3.

Human VKOR contains between 1-3 transmembrane domains depending on the TM-
35   prediction program used and the enzyme is probably integrated in the ER-membrane. One of the predicted TM-domains is located in the VKOR N-terminus (residues 10-29),

therefore, VKOR carries its own signal sequence. The signal sequence can be substituted by a yeast signal sequence e.g by the MF(alpha) signal sequence.

5   With the purpose of detecting VKOR expression or sub-cellular localisation, a set of con-
       structs have been created in which VKOR carries an HA-epitope tag: An EcoRI-EcoRI
       VKOR-containing fragment from 'pSX765' (see examples 1 and 3) was ligated with EcoRI
       digested and dephosphorylated 'pRS316-MF(alpha)1 promoter' (derived from the pRS
       series of plasmids described by Sikorski and Hieter, 1989, Genetics) using T4 DNA ligase
       (New England Biolabs). The resulting plasmid was termed 'VKOR pRS316 MF(alpha)1
10   promoter' (see FIG. 4). The sequence of plasmid 'VKOR pRS316 MF(alpha)1 promoter' is
       listed in SEQ ID NO:4.

       A EcoRI-HindIII VKOR-containing fragment from 'VKOR pRS316 MF(alpha)1 promoter'
       was cloned into EcoRI+HindIII digested and dephosphorylated 'pRS426 MF(alpha)1 pro-
15   moter'. The resulting plasmid is 'VKOR pRS426 MF(alpha)1 promoter'. (see FIG. 5). The
       sequence of plasmid is 'VKOR pRS426 MF(alpha)1 promoter' is listed in SEQ ID NO:5.

       A fragment encoding the VKOR C-terminus in frame with an HA-tag
       (tccggaaggtccaagaaccccagggcaaggctaagagggcatacccttacgatgttcctgactatgcgggct
20   atccctatgacgtcccggactatgccggatcctacccttacgacgttccagattacgcttgaagcttatcgat
       (SEQ ID NO:13)) was PCR amplified using the High-Fidelity polymerase (Roche).

       The sequence-verified BspE1+ClaI VKOR HA-tag fragment was ligated with BspE1+ClaI
       digested and dephophorylated 'VKOR pRS316-MF(alpha)1 promoter' (see above) using
25   T4 DNA ligase (New England Biolabs). The resulting plasmid was termed 'VKOR C HA-tag
       pRS316 MF(alpha)1 promoter' (see FIG. 6). The sequence of plasmid 'VKOR C HA-tag
       pRS316 MF(alpha)1 promoter' is listed in SEQ ID NO:6.

       A fragment containing VKOR-HA-tag was cloned using EcoRI+HindIII into 'pRS426
30   MF(alpha)1 promoter'. The resulting plasmid was termed 'VKOR C HA-tag pRS426
       MF(alpha)1 promoter' (see FIG. 7). The sequence of plasmid is 'VKOR C HA-tag pRS426
       MF(alpha)1 promoter' is listed in SEQ ID NO:7.

       Human gamma-carboxylase contains 5 transmembrane domains but no predictable signal
35   sequence. The enzyme is integrated in and acts at the level of the ER. myc-epitope car-
       rying versions of gamma-carboxylase have been created with the purpose of detecting
       expression or sub-cellular localisation. The in-house developed pRS313 (*MF(alpha)1
       promoter, HIS3, ARS/CEN*) or pRS423 (*MF(alpha)-1 promoter, HIS3*, 2-micron) plasmids,

derived from the pRS series of plasmids described by Sikorski and Hieter, 1989, Genet-
ics, have been used for generating carboxylase expression vectors: A PmeI digested
gamma-carboxylase containing fragment from pLN438 was ligated with EcoRV digested
and dephosphorylated 'pRS313-MF(alpha)1 promoter' to produce the plasmid 'gamma
5   carboxylase pRS313 MF(alpha)1 promoter' (see FIG. 8), or 'pRS423 MF(alpha)1 pro-
moter' to produce the plasmid 'gamma carboxylase pRS423 MF(alpha)1 promoter', re-
spectively. (see FIG. 9). The sequence of plasmids 'gamma carboxylase pRS313
MF(alpha)1 promoter' and 'gamma carboxylase pRS423 MF(alpha)1 promoter' are listed
in SEQ ID NO:8 and SEQ ID NO:9.

10

A myc-tagged gamma carboxylase C-terminus was PCR amplified
(cgccggcgaaatactcctttccatgagcgattcttccgcttcttgttgcgaaagctctatgtctttcgccgcag
cttcctgatgacttgtatctcacttcgaaatctgatattaggccgtccttccctggagcagctggcccaggaggtgacttatgcaa
acttgagaccctttgaggcagttggagaactgaatccctcaaacacggattcttcacattctaatcctcctgagtcaaatcctgat
15   cctgtccactcagagttcgctgaggagcaaaagttaatttctgaagaagatttgtccatggctgaagaacaaaaattgatcagc
gaggaggacttataaatcgat (SEQ ID NO:14)) using the plasmid 'gamma carboxylase pRS313
MF(alpha)1 promoter' as template.

The new C-terminus was cloned into 'gamma carboxylase pRS313 MF(alpha)1 promoter'
20   SgrA1+ClaI dephosphorylated vector using T4 DNA ligase (Roche). A corresponding ex-
ample was done using the plasmid gamma carboxylase pRS423 MF(alpha)1 promoter' as
template. The resulting plasmids are called 'gamma carboxylase C-term myc-tag
pRS313 MF(alpha)1 promoter' (see FIG. 10) and 'gamma carboxylase C-term myc-tag
pRS423 MF(alpha)1 promoter' (see FIG. 11), respectively. The sequence of plasmids
25   'gamma carboxylase C-term myc-tag pRS313 MF(alpha)1 promoter' and 'gamma car-
boxylase C-term myc-tag pRS423 MF(alpha)1 promoter' are listed in SEQ ID NO:10 and
SEQ ID NO:11.

Expression vectors encoding FVII, Vitamin K reductase and gamma-carboxylase can be
30   transformed into yeast cells for expression of active FVII. Expression of active FVII pro-
tein media samples or in cell lysates can then be demonstrated using antigen determina-
tion by ELISA and activity determination by clot assay.

35   All references, including publications, patent applications, and patents, cited herein are
hereby incorporated by reference to the same extent as if each reference were individu-
ally and specifically indicated to be incorporated by reference and were set forth in its
entirety herein (to the maximum extent permitted by law).

30

Any combination of the above-described elements in all possible variations thereof is encompassed by the invention unless otherwise indicated herein or otherwise clearly contradicted by context.

5

The use of the terms "a" and "an" and "the" and similar referents in the context of describing the invention (especially in the context of the following claims) are to be construed to cover both the singular and the plural, unless otherwise indicated herein or clearly contradicted by context.

10

The terms "comprising," "having," "including," and "containing" are to be construed as open-ended terms (i.e., meaning "including, but not limited to,") unless otherwise noted and should be read as encompassing the phrases "consisting", "substantially comprised of," and "consisting essentially of" (e.g., where a disclosure of a composition "compris-
15   ing" a particular ingredient is made, it should be understood that the invention also provides an otherwise identical composition characterized by, in relevant part, consisting essentially of the ingredient and (independently) a composition consisting solely of the ingredient).

20   Recitation of ranges of values herein are merely intended to serve as a shorthand method of referring individually to each separate value falling within the range, unless otherwise indicated herein, and each separate value is incorporated into the specification as if it were individually recited herein. Unless otherwise stated, all exact values provided herein are representative of corresponding approximate values (e.g., all exact ex-
25   emplary values provided with respect to a particular factor or measurement can be considered to also provide a corresponding approximate measurement, modified by "about," where appropriate).

All methods described herein can be performed in any suitable order unless otherwise
30   indicated herein or otherwise clearly contradicted by context.

The use of any and all examples, or exemplary language (e.g., "such as") provided herein, is intended merely to better illuminate the invention and does not pose a limitation on the scope of the invention unless otherwise claimed. No language in the specifi-
35   cation should be construed as indicating any non-claimed element as essential to the practice of the invention.

31

The citation and incorporation of patent documents herein is done for convenience only and does not reflect any view of the validity, patentability, and/or enforceability of such patent documents.

5   Preferred embodiments of this invention are described herein. Variations of those preferred embodiments may become apparent to those of ordinary skill in the art upon reading the foregoing description. The inventors expect skilled artisans to employ such variations as appropriate, and the inventors intend for the invention to be practiced otherwise than as specifically described herein. Accordingly, this invention includes all modifica-
10   tions and equivalents of the subject matter recited in the claims appended hereto as permitted by applicable law.

CLAIMS

1.   A method for preparing Vitamin K-dependent polypeptides in a carboxylation-deficient host cell, comprising co-expression of:

        a) A gamma-carboxylase

        b) A vitamin K reductase, preferably vitamin K 2,3-epoxide reductase (VKOR)

        c) A Vitamin K-dependent polypeptide.

2.   A method according to claim 1 wherein the Vitamin K-dependent polypeptide is selected from the following: factor VII, factor IX, factor X, prothrombin, protein C, protein S, protein Z, pulmonary surfactant-associated proteins, osteocalcin, proline-rich Gla protein 1, and matrix gla-protein.

3.   A method according to claim 1 wherein the Vitamin K-dependent polypeptide is factor VII.

4.   A method of enhancing Vitamin K-dependent polypeptide production in a carboxylation-competent host cell comprising either:

        a) Transfecting a carboxylation competent cell with either a gamma-carboxylase or a vitamin K 2,3-epoxide reductase, and a Vitamin K-dependent polypeptide, or

        b) Transfecting a carboxylation competent cell with a gamma-carboxylase, a vitamin K 2,3-epoxide reductase, and a Vitamin K-dependent polypeptide, or

        c)Transfecting a cell line, already expressing a Vitamin K-dependent polypeptide, with either a gamma-carboxylase or a vitamin K 2,3-epoxide reductase, or

        d) Transfecting a cell line, already expressing a Vitamin K-dependent polypeptide, with both a gamma-carboxylase and a vitamin K 2,3-epoxide reductase

5.   A method according to claim 4 wherein the Vitamin K-dependent polypeptide is selected from the following: factor VII, factor IX, factor X, prothrombin, protein C, protein S, protein Z, pulmonary surfactant-associated proteins, osteocalcin, proline-rich Gla protein 1, and matrix gla-protein.

6. A method according to claim 4 wherein the Vitamin K-dependent polypeptide is factor VII.

7. A method according to claim 1, wherein the carboxylation-deficient host cell is a non-vertebrate cell line.

8. A method according to claim 7, wherein the non-vertebrate cell line is a yeast cell.

9. A method according to claim 8, wherein the yeast cell is *Schizosaccharomyces*.

5

10. A method according to claim 8, wherein the yeast cell is a *Pichia*.

11. A method according to claim 8, wherein the yeast cell is *Saccahromyces*.

10   12. A method according to claim 7, wherein the non-vertebrate cell line is a plant-derived cell line.

13. A method according to claim 7, wherein the non-vertebrate cell line is a transgenic plant.

15

14. A method according to claim 7, wherein the non-vertebrate cell line is an insect cell line.

15. A method according to claim 4, wherein the host cell is a transgenic animal, and
20   wherein cDNAs for both a Vitamin K-dependent polypeptide, and a gamma-carboxylase or a vitamin K 2,3-epoxide reductase, has been introduced and is expressed.
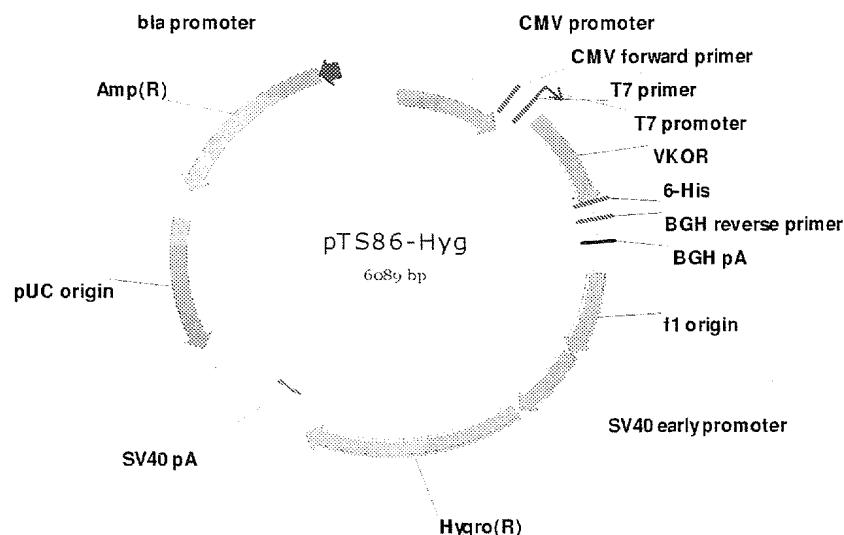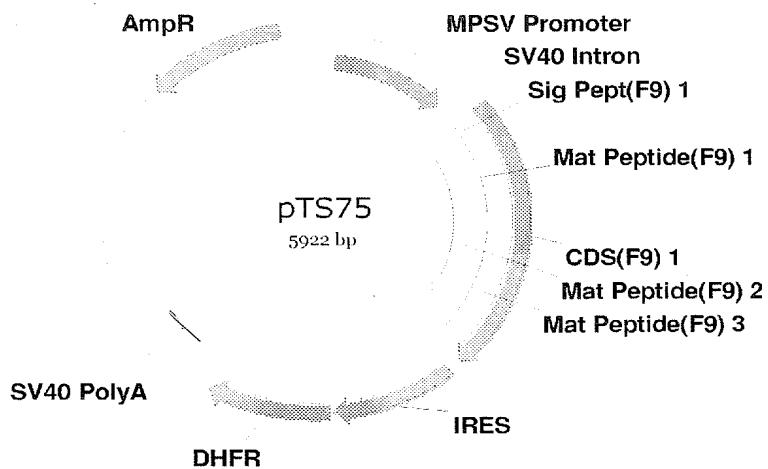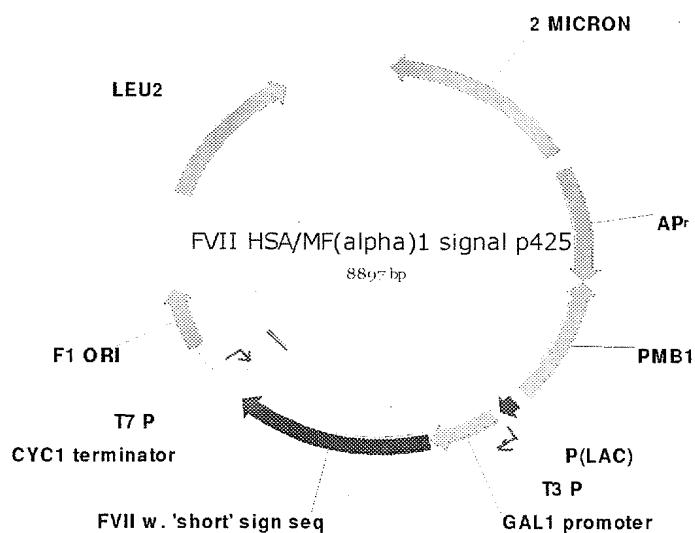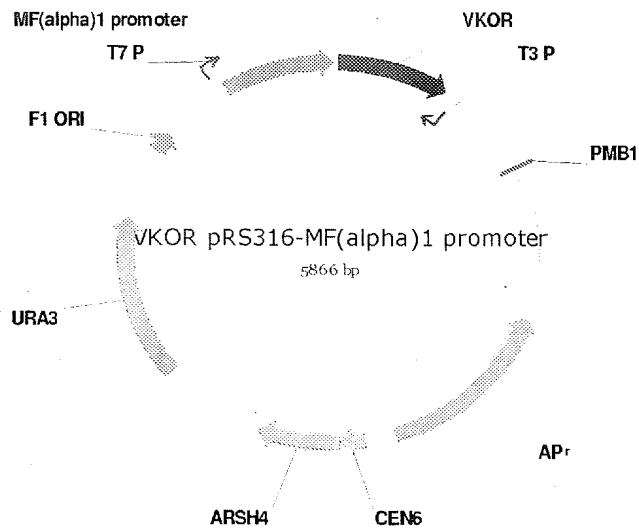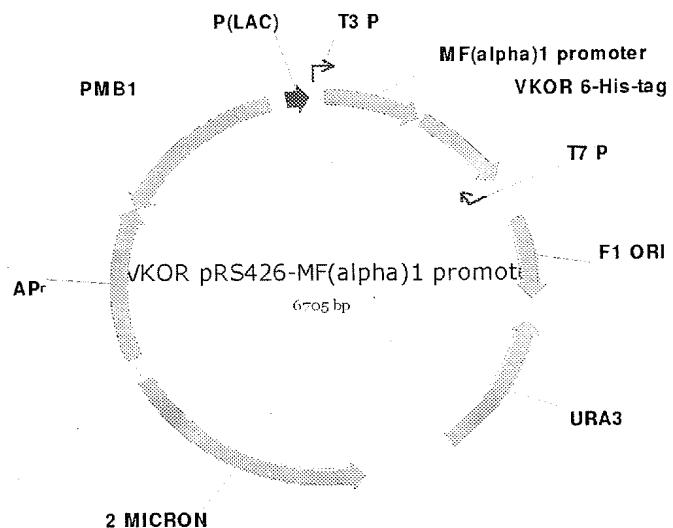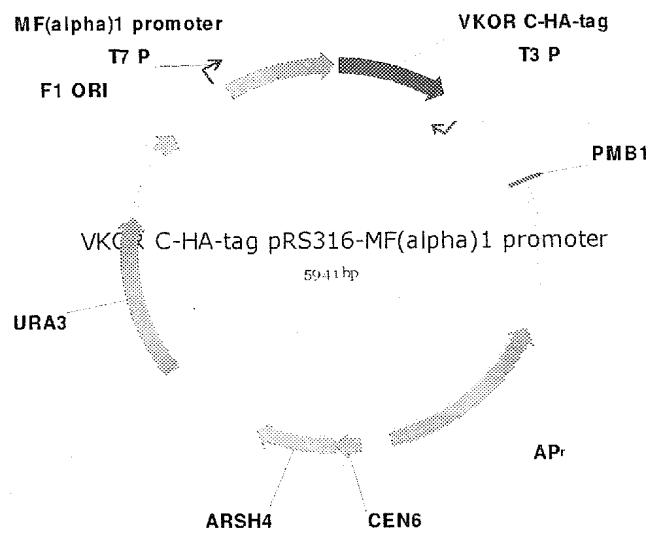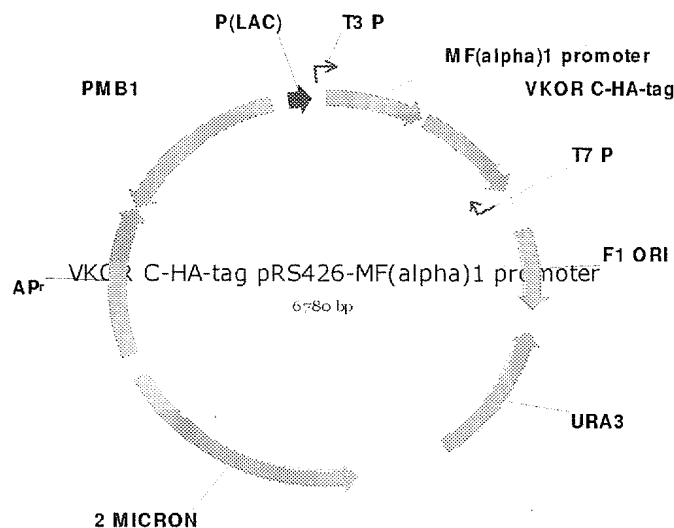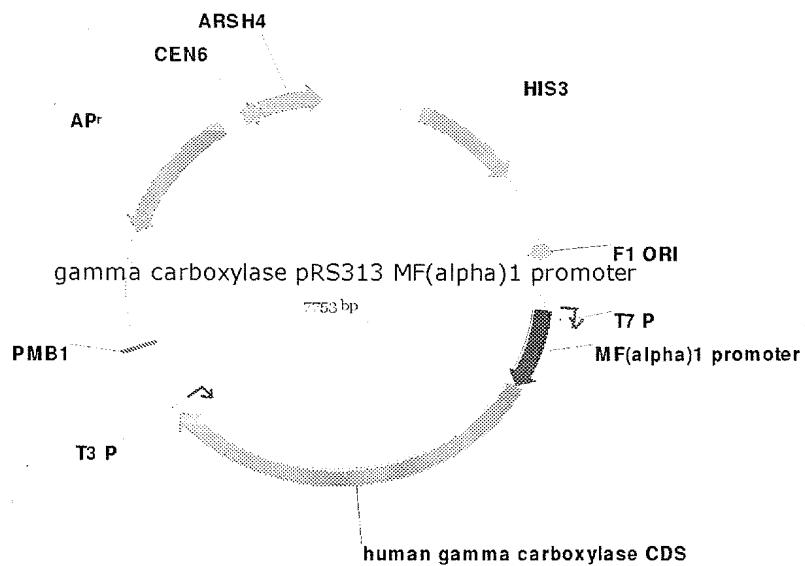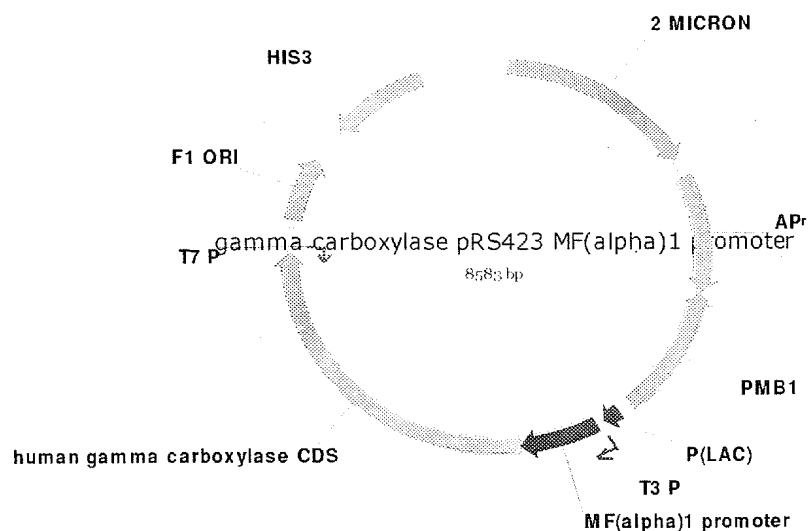
FIG. NO. 1

FIG. NO. 2

FIG. NO. 3

FIG. NO. 4

FIG. NO. 5

FIG. NO. 6

FIG. NO. 7

FIG. NO. 8

HIS3

2 MICRON

F1 ORI

APr

T7 P gamma carboxylase pRS423 MF(alpha)1 promoter
              858з bp

PMB1

human gamma carboxylase CDS

P(LAC)

T3 P

MF(alpha)1 promoter

FIG. NO. 9

ARSH4

CEN6

HIS3

APr

F1 ORI

gamma carboxylase C-term myc-tag pRS313 MF(alpha)1 promoter
              ¬8o6 bp

T7 P

MF(alpha)1 promoter

PMB1

T3 P

myc-tag

myc-tag

human gamma carboxylase
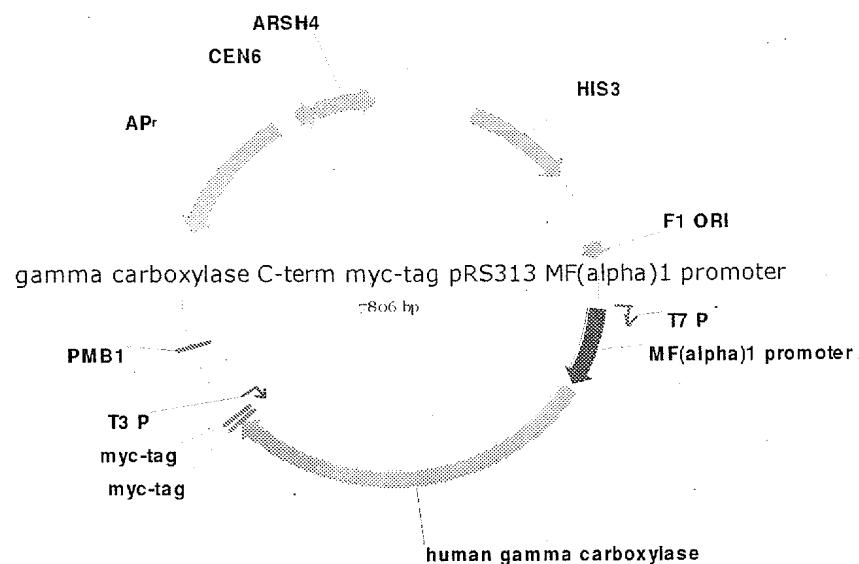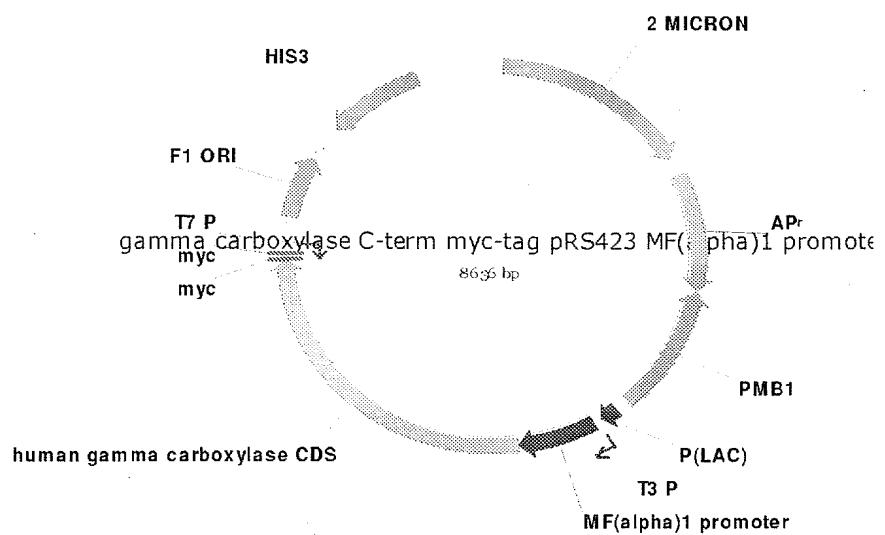
FIG. NO. 10

FIG. NO. 11

Box No. I	Nucleotide and/or amino acid sequence(s) (Continuation of item 1.b of the first sheet)

1. With regard to any nucleotide and/or amino acid sequence disclosed in the international application and necessary to the claimed invention, the international search was carried out on the basis of:

    a.   type of material

         [X]   a sequence listing

         [ ]   table(s) related to the sequence listing

    b.   format of material

         [X]   on paper

         [X]   in electronic form

    c.   time of filing/furnishing

         [X]   contained in the international application as filed

         [ ]   filed together with the international application in electronic form

         [X]   furnished subsequently to this Authority for the purpose of search

2. [X]   In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

3.   Additional comments:

INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
C12N9/64   C12N9/04   C07K14/745

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C12N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, BIOSIS, WPI Data, PAJ, FSTA

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WALLIN REIDAR ET AL: "Vitamin K 2,3-epoxide reductase and the vitamin K-dependent gamma-carboxylation system." THROMBOSIS RESEARCH, vol. 108, no. 4, 2002, pages 221-226, XP002375181 ISSN: 0049-3848 the whole document page 225, right-hand column, paragraph 2 -/--	1-15

[X] Further documents are listed in the continuation of Box C.   [ ] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
31 March 2006	24/04/2006

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Authorized officer Turri, M

Form PCT/ISA/210 (second sheet) (April 2005)

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	LI TAO ET AL: "Identification of the gene for vitamin K epoxide reductase" NATURE, NATURE PUBLISHING GROUP, LONDON, GB, vol. 427, no. 6974, 5 February 2004 (2004-02-05), pages 541-544, XP002318817 ISSN: 0028-0836 the whole document	1-15
P,X	WAJIH NADEEM ET AL: "Increased production of functional recombinant human clotting factor IX by baby hamster kidney cells engineered to overexpress VKORC1, the vitamin K 2,3-epoxide-reducing enzyme of the vitamin K cycle" JOURNAL OF BIOLOGICAL CHEMISTRY, vol. 280, no. 36, September 2005 (2005-09), pages 31603-31607, XP002375182 ISSN: 0021-9258 the whole document	1-15
P,X	WAJIH NADEEM ET AL: "Engineering of a recombinant vitamin K-dependent gamma-carboxylation system with enhanced gamma-carboxyglutamic acid forming capacity - Evidence for a functional CXXC redox center in the system" JOURNAL OF BIOLOGICAL CHEMISTRY, vol. 280, no. 11, March 2005 (2005-03), pages 10540-10547, XP002375189 ISSN: 0021-9258 the whole document	1-15
A	KAUFMAN R J ET AL: "EXPRESSION PURIFICATION AND CHARACTERIZATION OF RECOMBINANT GAMMA CARBOXYLATED FACTOR-IX SYNTHESIZED IN CHINESE HAMSTER OVARY CELLS" JOURNAL OF BIOLOGICAL CHEMISTRY, vol. 261, no. 21, 1986, pages 9622-9628, XP002375183 ISSN: 0021-9258	
A	REHEMTULLA A ET AL: "In vitro and in vivo functional characterization of bovine vitamin K-dependent gamma-carboxylase expressed in Chinese hamster ovary cells" PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF USA, NATIONAL ACADEMY OF SCIENCE, WASHINGTON, DC, US, vol. 90, no. 10, May 1993 (1993-05), pages 4611-4615, XP002204115 ISSN: 0027-8424	

—/—

INTERNATIONAL SEARCH REPORT

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WU S-M ET AL: "CLONING AND EXPRESSION OF THE CDNA FOR HUMAN GAMMA GLUTAMYL CARBOXYLASE" SCIENCE (WASHINGTON D C), vol. 254, no. 5038, 1991, pages 1634-1636, XP001246571 ISSN: 0036-8075	

Form PCT/ISA/210 (continuation of second sheet) (April 2005)